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CAN BIOFUELS ACCELERATE ENERGY SECURITY?

by

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Biography

CDR John Gay has 25 years of military experience in photography and public affairs. He began his naval service as an enlisted Photographer's Mate in 1988 and served in a variety of assignments, both at sea and ashore, through the rank of Chief Petty Officer. CDR Gay was commissioned in 1998 through the Limited Duty Officer program and redesignated to Public Affairs Officer in 2001. As a Photo LDO, CDR Gay served as Tactical Airborne Reconnaissance Officer for Fighter Squadron TWO and as Aide to Commander Naval Space Command. As a PAO, CDR Gay and served in a variety of assignments afloat, overseas and ashore. He has deployed in support of Operations Desert Shield/Desert Storm, Southern Watch, Iraqi Freedom and Enduring Freedom. CDR Gay will next report to United States Fleet Forces Command as the Deputy Public Affairs Officer, responsible for providing public affairs guidance to the Commander and subordinate commands in the area on manning, training and equipping the fleet.

Abstract

Unpredictable global security threats and volatile oil markets make it impossible for the United States to forecast its energy costs. The 2007 National Defense Authorization Act set an aggressive goal for the military to produce or procure 25 percent of all its energy demands from renewable sources by 2025 and the Obama Administration has identified energy as being at the center of its own vision for America's economic future. In partnership, the Department of Energy, Department of Agriculture, and the US Navy have made significant investments in developing and testing biofuels with the stated intent to create an industry that is capable of producing enough biofuel at a competitive price to decrease the nation's dependency on foreign oil and reduce the service's vulnerability to price shocks. Can military investment jumpstart a biofuels industry and provide an alternative to imported foreign oil that is compatible, readily available and affordable? This paper explores the military application and feasibility of biofuels and offers reasons why biofuels will not be cost competitive or available in necessary quantities and will put our service members at greater risk rather than improve energy security.

Introduction

The evolution of liquid fuel for transportation has a long history of innovation that started with the steam engine. Initially, wood or coal was a primary fuel source to propel various vehicles, both on land and at sea, but transferring wood and coal was dirty and strenuous work that required extensive manpower. The discovery of liquid petroleum and the development of refinery processes quickly shifted transportation energy from coal and wood to liquid fuels. Petroleum offers double the thermal energy of coal and as a result, boiler designs became smaller so automobiles, ships and railway locomotives could travel faster and farther. The transfer of liquid petroleum through pipes greatly reduced refueling labor and provided greater distribution options. As a result, petroleum quickly became the fuel of choice, initiated a global oil boom, and created competing global national interests.

Today, global economies as well as national security interests depend on domestic and imported oil. As that dependency grows, the fundamental stability of the global oil market is being stressed by inadequate investment in oil production capacity, persistent geopolitical instability, and rapidly growing demand in developing nations.[1] In addition, reliance on a single energy source for transportation fuel – petroleum – has economic, strategic, and environmental drawbacks. In response to these challenges, and controversially using cold-war authorities of the Defense Production Act, a memorandum of understanding was signed between the Secretaries of Agriculture, Energy and the Navy to each invest $170 million to attempt to jumpstart a biofuels industry and help lead the United States to energy independence.[2]

The 2007 National Defense Authorization Act set an aggressive goal for the military to produce or procure 25 percent of all its energy demands from renewable sources by 2025.[3]

> Section 2852 of the 2007 National Defense Authorization Act calls for the Department of Defense to establish goals regarding use of renewable energy to meet transportation needs:

> The Secretary of Defense shall submit to the congressional defense committees the energy performance goals for the Department of Defense regarding transportation systems, support systems, utilities, and infrastructure and facilities… (c) Special considerations.—For the purpose of developing and implementing the energy performance goals and energy performance plan, the Secretary of Defense shall consider at a minimum the following:… (4) Opportunities to pursue alternative energy initiatives, including the use of alternative fuels in military vehicles and equipment. (5) Cost effectiveness, cost savings, and net present value of alternatives... and (8) the value of the use of renewable energy sources.[4]

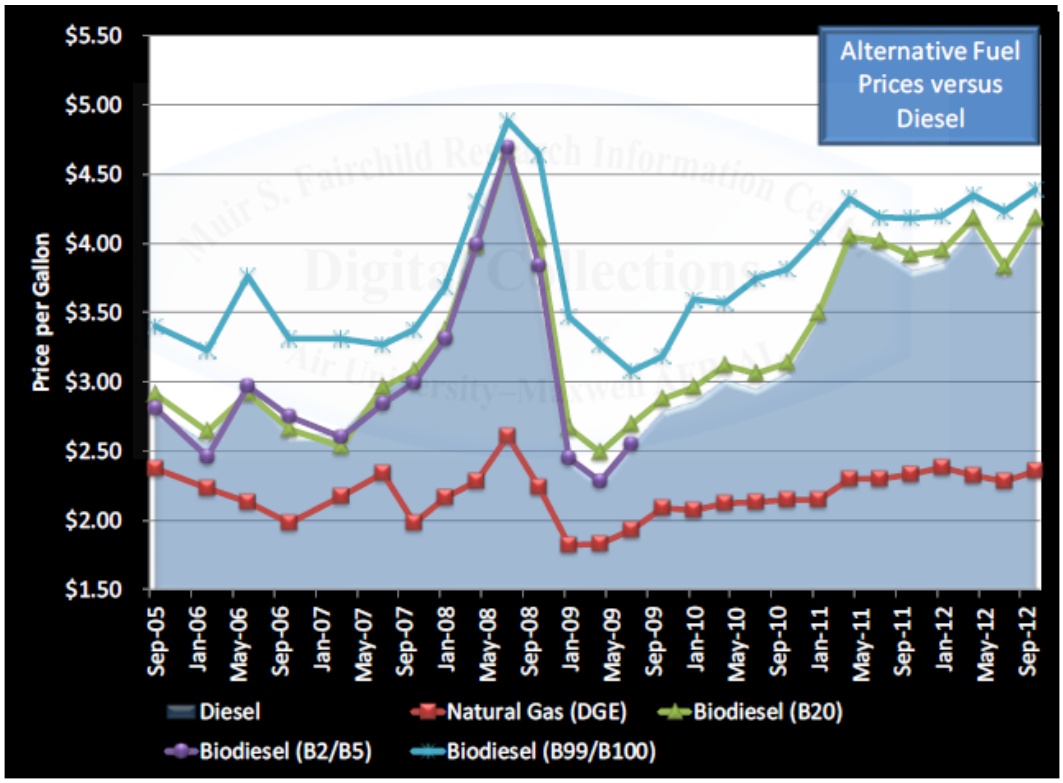
In compliance with the law, the US Army, Navy, Marine Corps, and Air Force have all expressed an interest in being early users of alternative fuels, although Congress did not require the use of alternative fuels in military tactical weapon systems. The Air Force played a lead role in evaluating and testing alternative fuels for military applications and set a goal to be prepared to acquire cost-competitive alternative fuel blends sufficient to meet 50 percent of its domestic aviation fuel requirements by 2016. Moving well beyond compliance with the will of Congress, Secretary of the Navy Ray Mabus established an aggressive energy strategy focused on replacing 50 percent of the Navy's energy consumption with biofuels by 2020.[5] The Army is evaluating the performance of alternative fuels in combat systems, but has not yet formally established goals.[6] Can military research and investment jumpstart a biofuels industry and provide an alternative to imported foreign oil that is compatible, readily available and affordable? This paper explores the military application and feasibility of biofuels and offers reasons why biofuels will not lead the nation to improved energy security.

Biofuel Defined

Biofuels are liquid fuels produced from agricultural or other biological materials and such fuels have been around for more than 125 years. Some of the first automobiles and tractors were capable of running on biofuel, and a commercial cellulosic ethanol plant first opened in the United States in 1910. Biofuels production declined over time because it was expensive, inefficient, and ultimately unsustainable.[7] Corn-based ethanol reappeared in the 1970s after the oil embargo as a way for the United States to reduce its dependency on imported oil from the Middle East, and it regained interest once again in the 1990s as a renewable fuel to help reduce greenhouse gas emissions.[8] Today, the most widely used biofuel – ethanol – is produced from the fermentation and distillation of sugar or starch-based crops such as sugarcane or corn. Biofuels also include biodiesel – mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats.[9] Biodiesel is renewable heating oil and a diesel substitute used in Europe, and is gaining interest in the commercial market in the United States. Common feedstock for biodiesel fuels include soybean, rapeseed, canola, palm, other plants, and waste cooking oils and animal fats.[10]

Untreated bio-oil made from thermal processing of tree and plant cellulose is a complex mixture of oxygenated organic compounds with about 25 percent water that is difficult to separate. Bio-oil is not compatible with conventional fuel systems and engines and it is unstable in long-term storage. [11] However, it can be stabilized and converted to a conventional hydrocarbon fuel by a complex sequence of steps called hydrotreating.[12] Once hydrotreated, biodiesel is compatible with petroleum-based fuels and miscible in many different concentrations offering “drop-in” advantages without diesel motor modification. However, hydrotreatment is costly in energy, and some scientists doubt that there is a net energy gain in biofuels because

more than 50 percent of the energy stored in feedstock plants comes from fossil fuels in the form of nitrogen fertilizers and pesticides, energy for tilling, harvesting and transport, and the chemical conversion process.[13] Because a significant amount of fossil fuel is required in the lifecycle production of biofuels, the cost of processing biomass into ethanol or biodiesel is directly linked to the cost of fossil fuels; when the price of oil increases, so too does the feedstock and production costs of biofuels. Biofuels and associated renewable energy credits are also part of the global energy trading market, and biofuels price trend in the same direction as fossil fuels as observed in Figure 1. As a result, it is unlikely that the costs of biofuels will ever



become more competitive than fossil fuels.[14]

Figure 1. Alternative Fuel Prices versus Diesel
(US Department of Energy, "Cities Alternative Fuel Price Report", July 2012, 15.)

Biofuels also do not offer the same energy density of petroleum-based fuels. Ethanol contains 33 percent less energy per gallon than gasoline and biodiesels contain about 8 percent less energy than petroleum-based diesel fuels.[15] Lower energy density has a direct negative effect on battlefield energy security. It means that operational vehicles using biofuels will travel less distance per tank of fuel and will require more fuel to accomplish the same mission. This results in additional logistics requirements in the form of more fuel that will have to be delivered to the troops.

Energy Security

Energy security is having assured access to reliable energy supplies and the ability to protect and deliver sufficient energy to meet essential requirements.[16] Improving United States energy security is principally about reducing costs to United States consumers from disruptions in the oil supply and having a robust supply portfolio.

In a 2011 speech on America's energy security delivered at Georgetown University, President Barack Obama echoed the conventional wisdom of biofuels:

> The United States of America cannot afford to bet our long-term prosperity, our long-term security on a resource that will eventually run out, and even before it runs out will get more and more expensive to extract from the ground. We cannot afford it when the costs to our economy, our country, and our planet are so high, not when your generation needs us to get this right. It is time to do what we can to secure our energy future.[17]

The transportation sector of the United States economy almost exclusively relies on petroleum – converted by refineries to gasoline, diesel, and jet fuel – making it most vulnerable to disruptions in the oil supply. The United States consumed slightly more than 250 billion gallons of refined petroleum in 2011. Sixty one percent of its crude is imported from foreign countries, 12.7 percent from the Persian Gulf.[18] In 2001, the Department of Defense consumed

5.2 billion gallons of refined petroleum products domestically, and another 4.05 billion gallons overseas or about 3.6 percent of the United States total refined petroleum consumed.[6]

Global economic growth has generated rapid increases in energy demand worldwide, and increased demand directly affects the price of crude. Crude oil prices jumped from $60 a barrel in mid-2005 to a spike of $140 a barrel in mid-2008. More recently, during the 12-month period from July 2011 to July 2012, the price of light crude oil fluctuated from under $80 a barrel to just over $110 a barrel.[19] Steady increases in petroleum prices have supported the United States government's justification for investing in biofuels development.[20] As a result, the volume of biodiesel produced in the United States has steadily increased over the past 10 years, as observed in Figure 2, but this is still only a very small fraction of the 202.7 billion gallons of petroleum consumed in the United States transportation sector in 2011.[21]

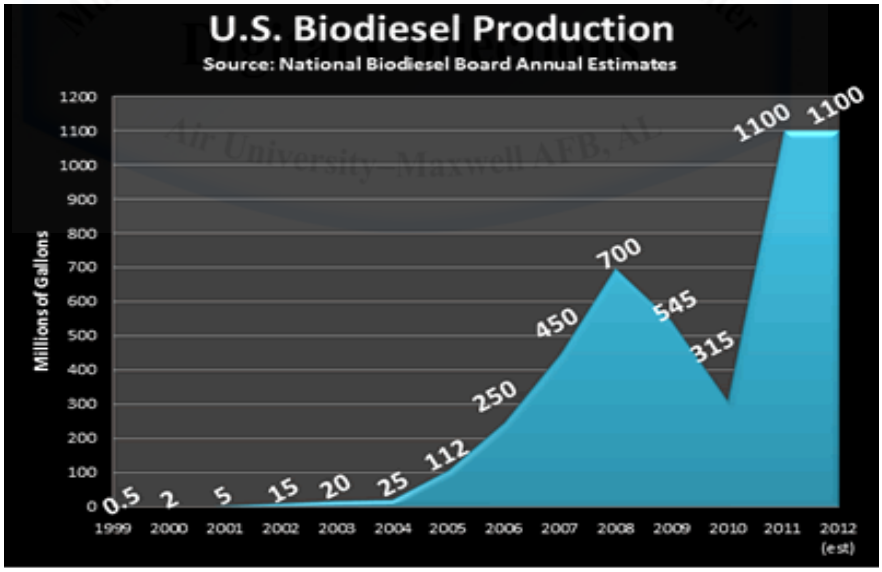


Figure 2. United States Annual Biodiesel Production
(National Biodiesel Board)

Despite the rising costs of crude, there is little hope that biofuels prices will ever be lower than the cost of petroleum. Even after all the billions of dollars in government subsidies, the current price of corn ethanol is $.40 a gallon higher than regular gasoline for the same amount of

energy in the gas tank.[22] Biodiesel prices range significantly higher. In 2009, the Defense Logistics Agency awarded small contracts for hydrotreated renewable HRJ-5 jet fuel that ranged in price from $66 to $149 per gallon.[23] Over the past few years, the Air Force and Navy staged several aircraft and ship demonstrations using compatible drop-in biodiesel and bio-jet fuel as a tactical fuel. In 2011, the Navy spent $12 million for 450,000 gallons of hydrotreated renewable jet fuel and diesel oil made from chicken fat and algae to support an exercise in the Pacific Ocean. The biodiesel used by the Navy cost $26.75 per gallon, nearly 10 times the costs of petroleum-based diesel fuel. That same $12 million biofuels purchase could have paid for more than three million gallons of conventional diesel fuel or the money could have been used to pay for other critical military programs.[24]

In Afghanistan, fuel reaches the front lines via rail, trucks and, in some cases, aircraft from Turkmenistan or Tajikistan. By some estimates, 70 percent of the convoys in the theater of war involve "liquid logistics" – the delivery of fuel and water. By the time fuel reaches our forward deployed troops, the fully burdened cost of fuel – the commodity fuel price plus the total cost of personnel and assets required to move and protect the fuel from the point it is received from the commercial supplier to the point of use – was estimated by the Marine Corps to range between $9 to $16 per gallon if delivered by land, and between $29 to $31 per gallon if delivered by air. In early 2009, Dr. Ashton Carter, Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L), testified to Congress that protecting fuel convoys imposes a huge burden on the combat forces and that by reducing the fuel demand, the services could reduce logistics assets, reduce operating costs and mitigate budget effects caused by fuel price volatility.[25] In addition, fuel convoys also increase casualty risks for service members from enemy attacks, improvised explosive devices, and bad weather and traffic accidents. According

to the Center for Army Lessons Learned, there was one casualty for every 24 fuel convoy in Afghanistan and one casualty for every 38.5 fuel convoys in Iraq. [26] Fuel convoys are extremely vulnerable to improvised explosive devises and, as shown in Figure 3, responsible for a large percentage of combat-related fatalities. Between July 2003 and May 2009, IEDs alone accounted for some 43 percent of United States fatalities in Iraq and 39.7 percent of fatalities in Afghanistan.[27]

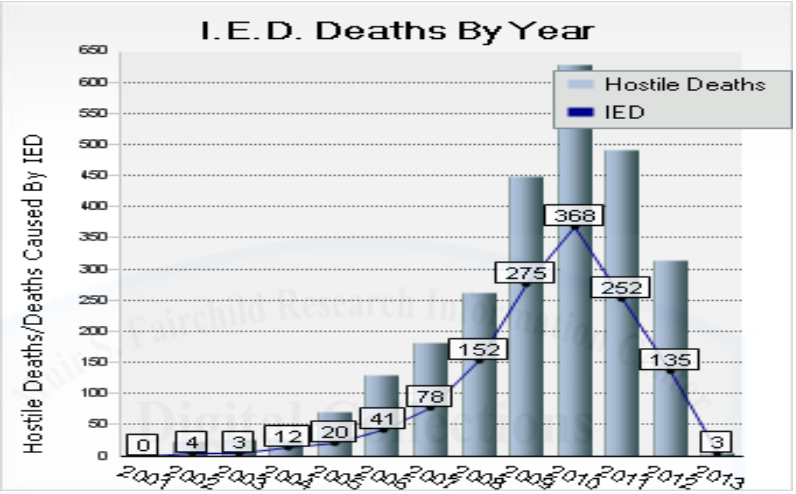


Figure 3. IED Deaths by Year, Afghanistan
(iCasualties.org)

Liquid fuels, whether petroleum-based or biofuels, have to be transported on the battlefield at the same cost and threat risks to our service members. For this reason, the use of biodiesel does not offer a tactical advantage for enhancing energy security and may increase the risks and number of casualties due to biofuels reduced energy density, which will require more fuel to accomplish the same mission.

In a 2011 report, the federally funded RAND National Defense Research Institute concluded that there is no direct benefit to the Department of Defense for using alternative fuels rather than petroleum-derived fuels.[28] The report further explained that biofuels do not offer a tactical military advantage, and unless the price of biofuels becomes more competitive and the

biofuels industry can scale up production, there is little chance the United States will significantly reduce its demand for petroleum-based fuels in the near future. The challenge of biofuels is production, not combustion.

Biofuels and Natural Resources

One of the biggest downsides to increasing biofuels production is that all biofuels compete with food agriculture for land, water, agrichemicals and other farming resources. About 40 percent of the corn grown in America today is used to produce ethanol as a gasoline additive, and food crops such as soybean, rapeseed, and palm are used to produce biodiesels. The large percentage of farmland used to grow corn for ethanol has only replaced 6.5 percent of America's gasoline energy. The ethanol industry expanded based partly on expectations that gasoline consumption would keep rising, and that ethanol's share of that growth would continue. Instead, gasoline demand for 2013 is projected to be 6.7% below its peak in 2007.[29] Agricultural markets are also volatile in price – when drought, flood, or freeze affects crop production, food costs as well as biofuels prices climb together, which is particularly damaging to an economy.[30] For example, the 2012 United States Midwest drought forced many ethanol bio-refinery plants to close and demonstrates the insecurity of a biomass fuel supply and its effects on energy security.

Land

Today, all biofuels produced in the United States and the European Union are consumed domestically, but current production capacities in both regions are a long way from meeting their own future targets without importing biomass feedstock. The demand for more biomass is happening at a time when there is a massive competition for other land use – including commercial forestry, food agriculture, industrial agriculture for textiles and chemicals, biomass for electrical power generation, and the expansion of urban areas.[31]

Available land necessary to meet future biofuel demands is unevenly divided across the world. North Africa, South Asia and Japan have very little arable land left for expansion, and almost half of the world's potentially available arable land is situated in only seven countries: Angola, Argentina, Bolivia, Brazil, Colombia, Democratic Republic of the Congo and Sudan.[32] Also competing with the United States and European Union for land expansion is China, India, Japan and South Korea. These nations continue to struggle to find additional agricultural land and they are leasing land in other nations, as well as trying to reclaim wasteland and saline land internally.[33]

One of the largest competing uses of land for biofuels production will be food crops needed to feed a growing world population. The grain it takes to fill a sport utility vehicle tank with ethanol could feed a person for a year.[34] This is a major concern when you consider that according to the United Nations, the world's population is expected to increase from 7 billion in 2011 to 9.3 billion by 2050.[35] One estimate predicts that by 2020 an extra 200 to 500 million hectares of additional land will be needed for food, animal feed, and pasture to meet the nutritional needs of the global population.[36]

According to Nobel Laureate Michel Hartmut, the growth of plants for biofuels will undoubtedly lead to an increase in food prices, which will predominantly hit poorer people.[37] The global community has yet to address the key drivers of recent food prices, which have spiked three times in the last five years. Estimates suggest that the 2008 food crisis forced 100 million people into poverty and some believe biofuels were responsible for at least 30 percent of the 2008 global food price spike. ActionAid, an international non-government organization, estimated at the time that 30 million more people went hungry as a direct result of biofuels.[38] Future estimates suggest global food prices could rise by as much as 76 percent by 2020, pushing

another 600 million more people into hunger if the United States and European Union biofuels goals are met and no other action is taken to prevent hunger.[39]

To meet the need for more land, a practice currently taking place around the globe is large-scale land acquisitions – frequently referred to as "land grabs." Land formerly used by independent farmers for their own subsistence is often confiscated by governments – with no respect for private land rights – and converted into plantations and crop monocultures. The agriculture products are then exported to feed the energy and food demands of the industrialized world with little consideration for the local economies.[40] This practice creates escalating local food prices, food scarcity, and loss of job opportunities forcing the displacement of people.[41] Oxfam International, a confederation of 17 different aid organizations operating in 90 different countries, estimates that 567 million acres of land in the developing world has been either sold, leased, licensed, or was currently under negotiation to foreign corporations between 2000 and today.[42] According to the Renewable Fuels Agency, an estimated 500 million more hectares of land – an area roughly half the size of Europe – is needed to meet the biofuel global demand by 2020. Land grabs are an example of how mandatory biofuel mandates are counterproductive to global security, to the supporting pillar of energy security, and to the United States' national security strategy.

Water

In addition to requiring more land, biofuels mandates also add pressure to natural water resources. Large-scale industrial agriculture operations are often located in major river basins and consume massive amounts of water.[43] According to the Intelligence Community Assessment, numerous countries have already over-pumped groundwater to satisfy a growing agricultural demand. This practice is counterproductive because degraded or depleted

groundwater produces fewer crops, and fewer crops leads to food security problems and possible social disruption.[44]

Currently one-in-three Africans already live in water scarce environments and global climate change is likely to increase these numbers significantly. According to Citigroup's chief economist, Willem Buiter, in the not so distant future water will become "the single most important physical commodity-based asset class, dwarfing oil, copper, agricultural commodities and precious metals."[45] Over the next 10 years, water problems will contribute to instability in regions important to United States national interests, and water shortages and poor water quality – when combined with poverty, social tensions, environmental degradation, and ineffectual government – contribute to social disruptions that can result in failed states.[46] Biofuels mandates in Europe and the United States pressure agricultural expansion and stress natural resources. These practices are detrimental to energy security and could possibly create increased security threats requiring United States military involvement in countries where there is currently little threat.

Algae

Some scientists suggest algae may offer biofuels solutions that will not compete with food agriculture or scarce water supplies. Algae are a potential energy source that can be converted into biodiesel and bio-jet fuel, and on paper, some scientists believe algae could replace worldwide petroleum use altogether.[47] Algae have been studied for many years for production of hydrogen, methane, vegetable oils, hydrocarbons and ethanol.[48] In 2006, after President George W. Bush declared that the United States was "addicted to oil," government algae research was resurrected and venture capital flowed into dozens of algae startups. Scientists and entrepreneurs have been trying to unlock the energy potential of algae for more

than three decades. Some companies grow algae in ponds, others grow them in clear plastic or glass tubes called bio-reactors, and others keep their algae away from sunlight, feeding them sugars instead.[49] The National Research Council committee concluded that current technology scaled up to produce 39 billion liters of algae-derived biodiesel per year –approximately 5 percent of the United States' transportation fuel needs – would require unsustainable levels of water and fossil fuel-based energy and fertilizer.[50] Current technologies require between 3.15 and 3650 liters of water to produce the amount of algae-biofuel equivalent to one liter of gasoline. As a comparison, petroleum requires 1.9 to 6.6 liters of water to produce one liter of gasoline.[51] Some argue that algae can be cultivated in saltwater, but even saltwater algae require all cooling water and evaporative make-up water to be fresh, or else salinity increases to lethal concentrations..

John Benemann, a biochemist who has spent more than 30 years working on algae, says "algae biofuels cannot compete with fossil energy based on simple economics." Researchers at the Lawrence Berkeley National Laboratory estimate that biofuels grown from algae in ponds at scale would cost between $240 and $332 a barrel, considerably higher than current petroleum prices.[52]For all these reasons, algae is not a viable option to support energy security at this time.

Recommendations

Improving United States energy security is principally about reducing the cost of energy to United States consumers and preventing disruptions in the oil supply. According to the 2010 National Security Strategy, the development of new sources of energy will reduce the United States' dependence on foreign oil and provide better energy security for the nation.[53] At this time, an investment in biofuels alone will not reduce our nation's thirst for foreign oil. The nation must employ other alternatives, such as improving efficiencies, using new technologies to

tap into domestic petroleum reserves and develop better conservation practices to reduce the demand for foreign petroleum.

Efficiency

Global consumption of petroleum will continue to grow about 1 percent per year and will remain the primary transportation fuel in the foreseeable future.[54] The United States is taking steps to produce more fuel-efficient automobiles by employing hybrid technology, developing lighter materials, and improving engine and transmission efficiency. Because of these initiatives, by 2020 the United States expects to see a reversing trend in domestic fuel consumption. Some of these fuel-efficient technologies are also compatible for use in military vehicles and can reduce the amount of fuel needed on the front lines. Investing in fuel-efficient technologies saves overall fuel costs and reduces the demand for petroleum, which enhances our energy security.

Conservation

Liquid fuels make up the majority of military logistics operations and requires thousands of personnel at an enormous cost in both money and human life. Up until a few years ago, military war-gaming did not even factor energy into the equation; it was simply assumed fuel would be available on time and where needed. Private industry case studies show behavior-based conservation methods often result in 20 percent or more in energy use reductions.[55] Recognizing that even small reductions in energy consumption can add up and make a big difference can greatly reduce the burden on logistics. Better planning, new doctrine, and conservation training can greatly enhance energy security for military operations.

Domestic oil and gas production

Up until just a couple of years ago, it appeared the United States was increasing its dependency on foreign oil imports, but today true energy independence has become a real

possibility, even without the development of alternative fuels. A dozen years ago, shale gas amounted to only about 2 percent of United States production; today, it is 37 percent and rising. Natural gas is in such ample supply that its price has plummeted. This unanticipated abundance has ignited a new political argument about liquefied natural gas – not about how much the United States will import but rather how much it should export.[56] According to a 2012 report published by Citigroup analysts, North America is "the new Middle East."[57] In 2011, the United States registered the largest increase in domestic oil production of any country outside of Organization of the Petroleum Exporting Countries (OPEC), and net petroleum imports have fallen from 60 percent of total consumption in 2005 to 42 percent today.[58] Analysts and economists believe that North America can achieve energy independence by 2020. Domestic oil and natural gas production has surged because of new technologies such as hydraulic fracturing and horizontal drilling, which allows companies to tap hydrocarbons trapped in shale and other tight rock formations. Government estimates suggest that domestic production of petroleum will rise another 22 percent, to 6.7 million barrels-per-day by 2020. At the same time domestic production is increasing, better efficiency and conservation practices are on track to reduce the amount of fuel American's consume by almost 10 percent.[59] Collectively these energy alternatives will greatly contribute to overall national energy security.

Conclusion

For the United States to achieve energy security, it must reduce its dependence on foreign oils. However, should the military – the branch of government responsible for the security of our nation – be responsible for investing its limited resources in the role of venture capitalist to jumpstart a biofuels industry and be forced to purchase fuels at 10 times higher costs than readily available petroleum-based fuels? Not only does this not make good economic sense, but it also

puts our national security at risk. Biofuel mandates divert scarce military resources away from critical programs such as weapons modernization, critical maintenance and necessary training and readiness. The United States military is the single largest consumer of liquid fuels in the world, but it still only accounts for 3.6 percent of the total United States annual consumption. This low percentage is not enough to spark a biofuels industry and affect overall fuel prices.

As this paper points out, biofuels are counterproductive to United States energy security because of four primary reasons. First, the cost of biofuels is directly linked to the cost of petroleum, as the price of petroleum increases so do biofuels. Second, biofuels are not currently available in the necessary quantities to meet the military's demand and it is unlikely that industry will ever be capable to produce enough supply. Third, biofuels energy density is significantly less than fossil fuels and less energy density mean less fuel efficiency. Less fuel efficiency means that there will be a need to increase the number of fuel convoys to meet the military's mission and this increases costs and risks to our service members. The fourth, and possibly the most compelling reason is the increased demand for biofuels feedstock will foster global threats and as a result, may increase the likelihood that our nation may have to respond by deploying military forces to new threat areas. Our military depends on the very best technology to meet the demanding roles of defending our nation, and for the aforementioned reasons petroleum will remain the best energy source for some time to come.

Notes

[1] Deloitte Development LLC, *Energy Security America's Best Defense: A study of increasing dependence on fossil fuels in wartime, and its contribution to ever higher casualty rates*, 2009, 4.

[2] Moshe Schwartz, Katherine Blakeley, and Ronald O'Rourke, *Department of Defense Energy Initiatives: Background and Issues for Congress*, Congressional Research Services, 10 December 2012, 18.

[3] *National Defense Authorization Act for Fiscal Year 2007*, Public Law 364, 109th Congress Sess. 2852, *Department of Defense goal regarding use of renewable energy to meet transportation needs*. (17 October 2006), 2496.

[4] *Ibid.*

[5] United States Navy, *The Department of the Navy's Energy Goals*, http://www.navy.mil/features/Navy_EnergySecurity.pdf

[6] James T. Bartis and Lawrence Van Bibber. *Alternative Fuels for Military Applications*, (Santa Monica, CA: RAND Corporation, 2011), http://www.rand.org/pubs/monographs/MG969, ix.

[7] Thomas Pyle, "The Navy's Use of Biofuels is Inefficient and Costly," *U.S. News and World Report*, 19 July 2012, http://www.usnews.com/opinion/blogs/on-energy/2012/07/19/the-navys-use-of-biofuels-is-inefficient-and-costly.

[8] Rick Newman, "More Evidence That It's Time to Dump Ethanol," *U.S. News and World Report*. 31 July 2012, http://www.usnews.com/news/blogs/rick-newman/2012/07/31/more-evidence-that-its-time-to-dump-ethanol.

[9] Energy Information Agency, "Biofuels in the U.S. Transportation Sector," February 2007, www.eia.gov/oiaf/analysispaper/biofuels_notes.html#133.

[10] *Ibid.*

[11] A. Oasmaa and E. Kuoppala. "Fast Pyrolysis of Forestry Residue. 3. Stability of Liquid Fuel." *Energy & Fuels, Vol.* 17 Issue 4, 2003, 1075-1084.

[12] S.B. Jones et al., *Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case*, (Richland, WA): Pacific Northwest National Laboratory February 2009, 4.3.

[13] Michael Hartmut, "The Nonsense of Biofuels," *Angewandte Chemie International*, 20 February 2012. http://onlinelibrary.wiley.com/doi/10.1002/anie.201200218/full.

[14] "Biofuel markets and policy impacts," *Biofuels: Prospects, Risks and Opportunities*, Food and Agriculture Organization of the United Nations. November, 2008, ftp://ftp.fao.org/docrep/fao/011/i0100e/i0100e04.pdf.

[15] U.S. Department of Energy, *Biodiesel Benefits and Considerations.* February 2011, http://www.afdc.energy.gov/fuels/biodiesel_benefits.html.

[16] *Energy Security, U.S. Code*, Title 10, Chap. 173, Sec.2924, Annual Department of Defense energy management reports, (3 January 2012).

[17] President Barack Obama, "America's Energy Security," (address, Georgetown University, Washington, D.C. 30 March 2011) http://www.whitehouse.gov/the-press-office/2011/03/30/remarks-president-americas-energy-security (accessed 28 January 2013)

[18] U.S. Crude Oil Imports by Country of Origin, http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbblpd_a.htm.

[19] Spot Prices for Crude Oil and Petroleum Products, Energy Information Administration, http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm (accessed 20 January 2013)

[20] Rosamond Naylor and William Wrigley, *Biofuels, Rural Development, and the Changing Nature of Agricultural Demand,* Center on Food Security and the Environment, Stanford Symposium Series on Global Food Policy and Food Security in the 21st Century, 11 April 2012, 6.

[21] U.S. Energy Information Administration, *Refinery Sales Volumes of Other Petroleum Products*, http://www.eia.gov/dnav/pet/pet_cons_refoth_d_nus_VTR_mgalpd_a.htm (accessed 21 January 2013).

[22] AAA Daily Fuel Gage Report, Oil Price Information Service, *National Average Fuel Prices*, http://fuelgaugereport.opisnet.com/index.asp (accessed 23 January 2013).

[23] Anthony Andrews et al, *The Navy Biofuel Initiative Under the Defense Production Act,* Congressional Research Services, 22 June 2012, 3.

[24] Thomas Pyle, "The Navy's Use of Biofuels is Inefficient and Costly," *U.S. News and World Report,* 19 July 2012, http://www.usnews.com/opinion/blogs/on-energy/2012/07/19/the-navys-use-of-biofuels-is-inefficient-and-costly.

[25] Deloitte Development LLC, *Energy Security America's Best Defense*: A study of increasing dependence on fossil fuels in wartime, and its contribution to ever higher casualty rates, 2009, 15.

[26] David S. Eady et al., *Sustain the Mission Project: Casualty Factors for Fuel and Water Resupply Convoys*, Army Environmental Policy Institute, September 2009, 6.

[27] Operation Iraqi Freedom, Operation Enduring Freedom Coalition Fatalities, http://icasualties.org/OEF/Index.asp (accessed 15 January 2013)

[28] James T. Bartis and Lawrence Van Bibber, *Alternative Fuels for Military Applications,* (Santa Monica, CA: RAND Corporation, 2011), http://www.rand.org/pubs/monographs/MG969, 83.

[29] Mark Peters, "Ethanol's Long Boom Stalls , Fuel-Additive Plants Close as Gasoline Demand Falls, Federal Mandates Are Met," *Wall Street Journal*. 11 June 2012, http://online.wsj.com/article/SB10001424052702303395604577434782358634706.html (accessed 10 December 2012).

[30] Rick Newman, "More Evidence That It's Time to Dump Ethanol," *U.S. News and World Report*. July 31, 2012, http://www.usnews.com/news/blogs/rick-newman/2012/07/31/more-evidence-that-its-time-to-dump-ethanol.

[31] Alan Broughton, "Sierra Leone - Land grabbing: A new colonialism,": *Globalfaultlines* http://axisoflogic.com/artman/publish/Article_65146.shtml. 16 November 2012.

[32] Renewable Fuels Agency, *Review of Indirect Effects of Biofuel, Evaluation of the drivers of land use change Review of future demand and supply of biofuels to 2020 and their impact on GHG-emissions*, 26 June 2008, http://www.globalbioenergy.org/uploads/media/0806_AEA_-_Review_of_indirect_effects_of_biofuels.pdf, 28.

[33] *Ibid*.

[34] David Roberts, *Why the military is trying to reduce its fossil fuel use*, 30 July 2012, http://grist.org/climate-energy/why-the-military-is-trying-to-reduce-its-fossil-fuel-use/

[35] United Nations, *World Urbanization Prospects The 2011 Revision.* United Nations Department of Economic and Social Affairs/Population Division, (New York, 2012), 1.

[36] E. Gallagher, *The Gallagher Review of the Indirect Effects of Biofuels Production.* Renewable Fuels Agency, UK, July 2008, http://www.unido.org/fileadmin/user_media/UNIDO_Header_Site/Subsites/Green_Industry_Asia_Conference__Maanila_/GC13/Gallagher_Report.pdf, 29.

[37] Dr. Michel Hartmut, "The Nonsense of Biofuels," *Angewandte Chemie International,* 20 February 2012. http://onlinelibrary.wiley.com/doi/10.1002/anie.201200218/full.

[38] Tim Rice. *Meals per gallon, the impact of industrial biofuels on people and global hunger*. ActionAid UK, http://www.actionaidusa.org/eu/publications/meals-gallon-impact-industrial-biofuels-people-and-global-hunger, 15 February 2010.

[39] *Ibid*.

[40] Alan Broughton, "Sierra Leone - Land grabbing: A new colonialism,": *Globalfaultlines* http://axisoflogic.com/artman/publish/Article_65146.shtml. 16 November 2012.

[41] Tim Rice. *Meals per gallon, the impact of industrial biofuels on people and global hunger*. ActionAid UK, http://www.actionaidusa.org/eu/publications/meals-gallon-impact-industrial-biofuels-people-and-global-hunger, 15 February 2010.

[42] *Ibid.*

[43] GRAIN, *Squeezing Africa Dry: Behind every land grab is a water grab*, http://www.grain.org/article/entries/4516-squeezing-africa-dry-behind-every-land-grab-is-a-water-grab, June 2012.

[44] Maria Otero, Global Water Security, Intelligence Community Assessment, (Washington DC, 9 May 2012), http://www.state.gov/j/189598.htm .

[45] *Ibid.*

[46] Schuyler Null, *Global Water Security Calls for U.S. Leadership, Says Intelligence Assessment,* NewSecurityBeat, http://www.newsecuritybeat.org/2012/03/global-water-security-calls-for-u-s-leadership-says-intelligence-assessment/, 26 March 2012.

[47] *Ibid.*

[48] John R. Benemann, *Opportunities and Challenges in Algae Biofuels Production,* http://www.fao.org/uploads/media/algae_positionpaper.pdf, 2008, 5.

[49] Marc Gunther, *Green Crude: The Quest to Unlock Algae's Energy Potential,* Yale Environment 360, http://e360.yale.edu/feature/green_crude_the_quest_to__unlock_algaes_energy_potential/2582/, 15 October 2012.

[50] Robert F. Service, *Large Scale Algae Biofuels Currently Unsustainable, New Report Concludes.* ScienceInsider. October 24, 2012.

[51] Robert F. Service, *Large Scale Algae Biofuels Currently Unsustainable, New Report Concludes.* ScienceInsider. October 24, 2012.

[52] Marc Gunther, *Green Crude: The Quest to Unlock Algae's Energy Potential,* Yale Environment 360, http://e360.yale.edu/feature/green_crude_the_quest_to__unlock_algaes_energy_potential/2582/, 15 October 2012.

[53] Office of the President of the United States, *National Security Strategy*, May 20102, 2.

[54] Pike Research, *Algae-Based Biofuels - Demand Drivers, Policy Issues, Emerging Technologies, Key Industry Players, and Global Market Forecasts,* http://www.pikeresearch.com/research/algae-based-biofuels (accessed 18 November 2012).

[55] John Laitner, Karen Ehrhardt-Martinez, and Vanessa McKinney, *Examining the Scale of the Behaviour Energy Efficiency Continuum,* The Foundation of Future Energy Studies, *http://www.mitenergyclub.org/assets/2009/10/25/LaitnerEA2009_EfficiencyBehaviorContinuum.pdf,* 2009, 218-219.

[56] Daniel Yergin, "America's New Energy Reality," *Dallas Morning News*. June 9, 2012.

[57] Tim Mullaney, *"U.S. Energy Independence is No Longer Just a Pipe Dream" USA Today, 15* May 2012.

[58] Daniel Yergin, "America's New Energy Reality," *Dallas Morning News*. June 9, 2012.

[59] Tim Mullaney, *"U.S. Energy Independence is No Longer Just a Pipe Dream," USA Today, 15* May 2012.

Bibliography

AAA Daily Fuel Gage Report. Oil Price Information Service. http://fuelgaugereport.opisnet.com/index.asp

Andrews, Anthony; Bracmort, Kelsi; Brown, Jared T. and Else, Daniel H. "The Navy Biofuel Initiative Under the Defense Production Act,: Congressional Research Service, June 22, 2012.

Bartis, James T. and Van Bibber, Lawrence. *Alternative Fuels for Military Applications,* Santa Monica, CA: RAND Corporation, 2011.

Benemann, John R. *Opportunities and Challenges in Algae Biofuels Production*. www.futureenergyevents.com/algae. 2008

Blakeley, Katherine., O'Rourke, Ronald., Schwartz, Moshe. *Department of Defense Energy Initiatives: Background and Issues for Congress*. Congressional Research Services. June 5, 2012.

Broughton, Alan. *Sierra Leone - Land grabbing: A new colonialism*. Globalfaultlines. November 16, 2012.

Deloitte Development LLC. "Energy Security America's Best Defense." 2009.

Energy Security, U.S. Code, Title 10, Chap. 173, Sec.2924, Annual Department of Defense energy management reports. 3 January 2012.

Energy Information Agency, "Biofuels in the U.S. Transportation Sector," February 2007, www.eia.gov/oiaf/analysispaper/biofuels_notes.html#133.

Fahey, Jonathan. Exxon: "US energy revival has staying power." *Associated Press*. 11 December 2012.

Gallagher, E. *The Gallagher Review of the Indirect Effects of Biofuels Production.* Renewable Fuels Agency, UK, July 2008.

GRAIN. *Squeezing Africa Dry: Behind every land grab is a water grab.* http://www.grain.org/article/entries/4516-squeezing-africa-dry-behind-every-land-grab-is-a-water-grab. June 2012.

Gunther, Mark. Green Crude: *The Quest to Unlock Algae's Energy Potential*. Yale Environment 360. 15 October 2012.

Hartmut, Michel, Dr. *The Nonsense of Biofuels*. Angewandte Chemie International Edition. 20 February 2012.

Jones, S.B., Holladay, J.E., Valkenburg, C. Stevens, D.J., Walton, C.W., Kinchin, C., Elliott, D.C., Czernik S. *Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: A Design Case*. Prepared for the U.S. Department of Energy Pacific Northwest National Laboratory. Richland, WA. February 2009.

Mullaney, Tim. "U.S. energy independence is no longer just a pipe dream." *USA Today*. 15 May 2012.

Office of the President of the United States, *National Security Strategy*, May 2010.

Operation Iraqi Freedom, Operation Enduring Freedom Coalition Fatalities, http://icasualties.org/OEF/Index.asp (accessed 15 January 2013).
National Defense Authorization Act for Fiscal Year 2007, Public Law 364, 109th Congress Secs. 2852, Department of Defense goal regarding use of renewable energy to meet transportation needs. 17 October 2006.
Naylor, Rosamond and Wrigley, William. *Biofuels, Rural Development, and the Changing Nature of Agricultural Demand.* Center on Food Security and the Environment, Stanford Symposium Series on Global Food Policy and Food Security in the 21st Century. April 11, 2012.
Newman, Rick. "More Evidence That It's Time to Dump Ethanol." *U.S. News and World Report*. July 31, 2012.
Null, Schuyler. *Global Water Security Calls for U.S. Leadership, Says Intelligence Assessment.* http://www.newsecuritybeat.org/2012/03/global-water-security-calls-for-u-s-leadership-says-intelligence-assessment/. March 26, 2012.
Oasmaa A and E Kuoppala. "Fast Pyrolysis of Forestry Residue. 3. Stability of Liquid Fuel." *Energy & Fuels. Vol.* 17 Issue 4, ACS Publications, pages 1075-1084, 2003.
Otero, Maria. *Global Water Security,* Intelligence Community Assessment, Washington DC, 9 May 2012.
Peters, Mark. "Ethanol's Long Boom Stalls , Fuel-Additive Plants Close as Gasoline Demand Falls, Federal Mandates Are Met." *Wall Street Journal*. 11 June 2012.
Pyle, Thomas. "The Navy's Use of Biofuels is Inefficient and Costly." *U.S. News and World Report.* July 19, 2012.
Renewable Fuels Agency. *Review of Indirect Effects of Biofuel, Evaluation of the drivers of land use change Review of future demand and supply of biofuels to 2020 and their impact on GHG-emissions.* 26 June 2008.
Rice, Tim. *Meals per gallon, the impact of industrial biofuels on people and global hunger*. ActionAid UK. 15 February 2010.
Roberts, David. Why the military is trying to reduce its fossil fuel use. http://grist.org/climate-energy/why-the-military-is-trying-to-reduce-its-fossil-fuel-use/. 30 July 2012.
Service, Robert F. *Large Scale Algae Biofuels Currently Unsustainable, New Report Concludes.* ScienceInsider. October 24, 2012.
U.S. Department of Energy. *Biodiesel Benefits and Considerations*. http://www.afdc.energy.gov/fuels/biodiesel_benefits.html
U.S. Energy Information Administration. Refinery Sales Volumes of Other Petroleum Products. http://www.eia.gov/dnav/pet/pet_cons_refoth_d_nus_VTR_mgalpd_a.htm
United States Navy, The Department of the Navy Energy Goals, http://www.navy.mil/features/Navy_EnergySecurity.pdf
United Nations, *World Urbanization Prospects The 2011 Revision.* United Nations Department of Economic and Social Affairs/Population Division, New York. 2012.
Yergin, Daniel. "America's New Energy Reality." *Dallas Morning News.* 9 June 2012.